Exercise Problems for Module 5

[**P5.1**] In the developement of the angular velocity vector, we defined a space-fixed and a body-fixed angular velocity vector. Can you think of any example where the body-fixed angular velocity would be natural to use?

[**P5.2**] Derive the *space-fixed* and *body-fixed* angular velocity matrices and vectors for a rotation matrix obtained from a $X - Y - Z$ Euler angle rotations of a rigid body.

[**P5.3**] Given a rotation matrix ${}^{A}_{B}[R]$ in terms of axis and angle, i.e., as $[R(\hat{\mathbf{k}}, \phi)]$, obtain the *space-fixed* and *body-fixed* angular velocity vector components in terms of $\hat{\mathbf{k}}$ and ϕ and their derivatives with respect to time.

[**P5.4**] Derive the velocity propagation equations for a serial manipulator with two consecutive links connected by prismatic (P) joints.

[**P5.5**] Using MAPLE or otherwise derive the expressions for the elements of the Jacobian matrix of a PUMA 560 robot described in Module 2.

[**P5.6**] Obtain the Jacobian matrix for the planar 3R manipulator in $\{Tool\}$. What is the general rule for transforming a $6 \times n$ Jacobain matrix between two coordinate systems?

[**P5.7**] Prove that [g] is positive definite. Obtain the eigenvectors for [g] corresponding to the eigenvalues λ_1 and λ_2. What do the eigenvectors mean?

[**P5.8**] For the five-bar mechanism shown in problems for Module 4 *see Problems-4.pdf* obtain $[K]$, and $[K^*]$. Describe geometrically, similar to the planar four-bar example, what happens when $\det([K^*]) = 0$.

[**P5.9**] Write a program to search and obtain another configuration of the three- degree-of-freedom manipulator where linear velocity ellipsoid degenerates to an ellipse.

[**P5.10**] Write a program to search and obtain another configuration where the three- degree-of-freedom manipulator gains a degree of freedom.

[**P5.11**] Obtain the force transformation matrix for the three- degree-of-freedom parallel manipulator discussed in Example 5.3.

[**P5.12**] For a six- degree-of-freedom serial manipulator in a singular configuration, it is known that all the joint axes intersect a line perpendicularly. For the PUMA 560 discussed in Module 2, verify this fact and obtain the equation of this line.